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Original Article

A simple predictive formula for the blood requirement in patients with high-energy blunt injuries transferred within one hour post-trauma

Yukio Akasaki,[1] Hiroshi Sugimori,[1] Kenta Momii,[1] Tomohiko Akahoshi,[1] Suguru Matsuura,[1] Yukihide Iwamoto,[2] Yoshihiko Maehara,[1] and Makoto Hashizume[1]

[1]*Emergency and Critical Care Center, Kyushu University Hospital; and* [2]*Department of Orthopaedic Surgery, Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan*

Aims: To recognize patients who require massive transfusion at the early stage of blunt trauma, we retrospectively investigated patients with high-energy blunt injuries transferred within 1 h post-trauma.

Methods: Between August 2007 and July 2011, 233 trauma patients were: (i) injured by a high-energy blunt mechanism with Injury Severity Score ≥9; (ii) not dead on arrival; (iii) older than 9 years; and (iv) at our center within 1 h after injury. The findings for 113 of those patients were analyzed, including those produced by ultrasonography, computed tomography, and arterial blood gas analyses.

Results: Of 113 patients, 33 underwent massive transfusion (≥6 units) within 8 h of arrival. A logistic regression analysis revealed that an arterial lactate level ≥28 mg/dL ($P < 0.001$; odds ratio, 105.11; 95% confidence interval, 12.58–2,718.84) and a flat ratio of the inferior vena cava on computed tomography ≥3 ($P < 0.001$; odds ratio, 32.50; 95% confidence interval, 4.44–714.44) were significant independent predictors for a massive transfusion within 8 h. In a receiver operating curve analysis, the area under the curve of the need for massive transfusion was 0.956, with a sensitivity of 0.94 and a specificity of 0.90. A linear predictive formula for the probability (P) of receiving a massive transfusion was generated as P = 2 × lactate (mg/dL) + 15 × the flat ratio of inferior vena cava − 103. Using another 52 trauma patients, the formula was validated.

Conclusions: An elevated level of arterial lactate and the flat ratio of inferior vena cava were significant predictors for identifying the patients who would require a massive transfusion in the early stage after high-energy blunt trauma.

Key words: Arterial blood gases, flat ratio, inferior vena cava, lactate, massive transfusion, trauma

INTRODUCTION

IN THE INITIAL management of patients with high-energy blunt trauma, both interventions for hemostasis and proper preparation of blood products are crucial to prevent hemorrhagic shock, which can easily lead to early death. Therefore, the concept of "the golden hour" has emerged as the centerpiece of care after high-energy trauma in Advanced Trauma Life Support.[1] One of the fundamental issues regarding blood products preparation is whether a patient will need a massive transfusion (MT) or not, and if so, how to recognize the need earlier.[2,3] This is particularly important in the care of patients injured by blunt mechanisms, because significant internal injuries may be difficult to detect on physical appearance alone in such patients. In addition, more than 90% of severe trauma patients have been reported to be injured by blunt mechanisms in Japan.[4]

Various factors, such as the findings on physical examination,[5,6] metabolic markers,[7,8] coagulation products,[9] and radiographic assessments,[10] have been proposed to recognize trauma patients who are in a hypoperfusion state and thus need an MT. However, the most important predictor of the necessity of an MT among these variables has yet to be determined. In most of the recent research in the civilian population, patients with both blunt and penetrating injury mechanisms were analyzed altogether. The interval from the injury onset and the admission to emergency department (ED) was also not sufficiently considered.

In this study, we focused on severe trauma patients who were transferred within 1 h of blunt trauma. We assessed the

Corresponding: *Hiroshi Sugimori, MD, PhD, Emergency and Critical Care Center, Kyushu University Hospital, 3-1-1 Maidashi, Higashi-ku, Fukuoka, 812-8582, Japan. E-mail: sugimori@intmed2.med.kyushu-u.ac.jp.*

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predictive values of the above-mentioned factors for an MT in these patients. We also aimed to define a simple predictive formula for the need for an MT using parameters readily obtainable at ED presentation, such as the results of the physical evaluation, laboratory data, and radiographic examinations.

PATIENTS AND METHODS

Patients

KYUSHU UNIVERSITY HOSPITAL has a university-based trauma center in an urban area to treat high-energy injured patients. Approximately 250 trauma patients are transferred to our ED each year. About 40% of those have an injury severity score (ISS) ≥9, and 96% are suffering from blunt injury mechanisms. With the approval of our institutional review board, we retrospectively reviewed 346 trauma patients with ISS ≥9 who were directly transferred to our center between August 1, 2007 and July 31, 2011. Patients were included in the current study if they were: (i) injured by a high-energy blunt mechanism; (ii) not dead on arrival; (iii) older than 9 years (from this age, normal systolic blood pressure and heart rate become over 100 mmHg and below 90/min, respectively); and (iv) presented to our center within 1 h of injury. The definition of a high-energy blunt mechanism was as follows: high speed crash and/or highly-damaged vehicle; death of fellow passenger; passenger released out of a vehicle; passenger run over or hit over 5 m by a motor vehicle; large distance between passenger and motorcycle; fall from a height over 6 m; or caught in a machine. Among the 233 patients who fulfilled the above criteria, some of the information described below was lacking for 120 patients, and therefore, these patients were also excluded. The data for the remaining 113 patients were analyzed.

Parameters

For each patient, data regarding the demographics (age and gender), injury characteristics (interval between the onset of injury and the arrival at the ED, injury mechanism), and vital signs on arrival were collected. As was customary at our center, a blood sample was drawn contemporaneously with the recording of vital signs for measuring the blood cell counts and blood gases (Radiometer ABL 700 Series, Copenhagen, Denmark) in the ED. These data were included as data in the primary survey. Coagulation studies, such as the fibrin, fibrinogen degradation products and international normalized ratio of prothrombin time (PT-INR) were carried out in the central laboratory. Positive findings on ultrasonography or computed tomography (CT) scans, i.e., fluid collection on focused assessment with sonography for trauma (FAST positive) and the maximal transverse to anteroposterior ratio (the flat ratio[10]) of the inferior vena cava (IVC) at the level of the renal vein on CT, were examined. These were considered as the data according to the secondary survey. The Abbreviated Injury Scale of the head, chest, abdomen, and pelvis, and the calculated ISS were also determined. The units of packed red blood cells (PRBCs) used for transfusion were counted if they were initiated within 8 h from the time of arrival, and the patients who received 6 units or more of blood were defined as having received an MT in order to recognize early need for preparation of blood products. This was based on evidence that hemorrhagic deaths typically occur early, within the first 3–6 h of patient arrival, and is the most common cause of preventable death within 6 h from admission.[11] Blood transfusion was applied to the patients with a hemodynamic instability such as hypotension and low hemoglobin (<8.0 g/dL) following fluid resuscitation over 3,000 mL. The intervention for hemostasis, mortality rate at discharge, and causes of death were also examined.

Grouping and statistical analyses

The patients were divided into two groups according to whether they received an MT within 8 h of arrival at the hospital. Group comparisons were carried out by Student's *t*-test or the χ^2-test, based on the nature of the parameter. As the current study was retrospective, a P-value < 0.01 was considered to be statistically significant to eliminate type I error as much as possible. The variables that were found to be significant were used in the subsequent multivariate logistic regression analysis. First, the significant variables that were obtained in the primary survey were entered into the multivariate stepwise regression models (backward elimination, $P < 0.05$ in this case). Second, the variables that were available in the secondary survey were added to a multivariate stepwise regression analysis that was done, along with primary survey variables. Finally, receiver operator curves were generated to evaluate the predictive strength of the most important factors for the need for an MT. The area under the curve (AUC), sensitivity, specificity, and linear predictive formula for the probability of the need for an MT were determined. The data were expressed as the means ± standard deviations. All statistical analyses were carried out using the JMP version 9.0.2 software program (SAS Institute, Cary, NC, USA).

Validation study

For the validation of the predictive formula generated in this study, we reviewed an additional consecutive 84 trauma patients with ISS ≥9 who were directly transferred to our center between August 1, 2011 and March 31, 2013. Arterial lactate level or the flat ratio of the IVC on CT was lacking for 32 patients; therefore, the data of the remaining 52 patients were analyzed.

RESULTS

THE OVERALL CLINICAL characteristics of the patients were as follows: the average age was 45.9 ± 21.1 years; males accounted for 63.4% of the patients; and the mean interval between the onset of injury and the arrival at hospital (Interval) was 34.1 ± 10.2 min. The mechanisms of injury were traffic accidents in 74.1% of the patients, falls from a height in 21.4% and other blunt mechanisms in 4.5%. The number of patients who underwent an MT within 8 h was 33 (29.2%).

The clinical characteristics according to whether the patient received an MT are summarized in Table 1. All data were considered as independent variables. We found no significant differences in the age, gender distribution, Interval, injury mechanisms, or mortality rate between the two groups. In terms of the vital signs on arrival, the patients who received an MT showed a significantly lower systolic blood pressure (SBP) and a higher heart rate (HR) compared with the group that did not received an MT. Among the laboratory findings, significant differences in the arterial lactate, glucose, and hemoglobin levels, and in the PT-INR, were found between the two groups. Those who received an MT showed a significantly flatter IVC, higher frequencies of FAST positive, abdomen and pelvic AIS ≥3, and higher ISS values than those who did not receive an MT. The patients who received MT had six operations and 11 trans-arterial embolization procedures for hemostasis, whereas those who did not receive MT had no operations and three trans-arterial embolization procedures.

Table 2 shows the results of the logistic regression analysis. Eleven candidate predictors of the need for an MT were selected on the basis of the results of the univariate analyses, and a cut-off value was determined for each predictor. Of the six factors examined in the primary survey, the logistic regression analysis identified a lactate level ≥28 mg/dL ($P < 0.001$; odds ratio, 17.56; 95% confidence interval [CI], 5.06–71.23) and a FAST positive finding ($P = 0.048$; odds ratio, 5.13; 95% CI, 1.00–26.15) as significant independent predictors of the need for an MT. When all the factors obtained by the primary and secondary surveys were included, a lactate level ≥28 mg/dL ($P < 0.001$; odds ratio, 105.11; 95% CI, 12.58–2,718.84), and a flat ratio of the IVC ≥3 ($P < 0.001$; odds ratio, 32.50; 95% CI, 4.44–714.44) were identified as the most important predictors of the need for an MT.

Figure 1 depicts the receiver operator curve analysis of the lactate level, FAST positive findings, and the flat ratio of the IVC for predicting the need to receive an MT. The AUC values for the lactate level, FAST positive findings, and the flat ratio of the IVC were 0.879, 0.614, and 0.850, respectively. When a combination of the lactate level and FAST positive findings was used, which included the results obtained from only the primary survey, the AUC was 0.892, with a sensitivity of 0.82 and a specificity of 0.83. When a combination of the lactate level and the flat ratio of the IVC was used, which included the findings from both the primary and secondary surveys, the AUC increased to 0.956, with a sensitivity of 0.94 and a specificity of 0.90. A linear predictive formula for the probability of receiving an MT was defined as follows:

$$\mathrm{P} = 2 \times \text{lactate}\,(\text{mg/dL}) + 15 \times \text{the flat ratio of IVC} - 103,$$

where a patient will receive an MT if the P value is positive. The generalized R-squared value and misclassification rate were calculated to be 0.73 and 0.12, respectively.

Subsequently, 52 patients who were not included in generating this predictive formula were assigned to validation analysis. Among 19 patients who received an MT, 16 patients showed positive P values using the predictive formula. Likewise, 31 patients out of 33 patients who did not receive an MT showed negative P values. Overall accuracy rate of the predictive formula in validation was 0.904 (47/52) with a sensitivity of 0.84 and a specificity of 0.94 (Table 3 and Appendix Fig. A1).

DISCUSSION

IN THE PRESENT study, we show that two factors, namely the arterial lactate level and the flat ratio of the IVC on CT, were significant predictors of the need to receive an MT in blunt high-energy trauma victims who were transferred within 1 h post-trauma. The overall accuracy of the prediction for receiving an MT was increased when these two variables were combined. Moreover, a simple linear predictive formula for the probability of receiving an MT was determined, and the formula was shown to be predictive for an MT with high accuracy in the validation analysis.

The ideal predictive model of the need for an MT should be simple and accurate, and there has been a growing interest in establishing clear guidelines for an MT protocol in the civilian population.[12–15] Examining 596 trauma patients with blunt or penetrating injuries, Nunez *et al*.[13] validated three previously described MT scoring systems, the Trauma-Associated Severe Hemorrhage (TASH) scores, McLaughlin scores, and the Assessment of Blood Consumption (ABC)

Table 1. Comparison of clinical characteristics between patients with high-energy blunt injuries transferred within one hour post-trauma who received and did not receive a massive transfusion (MT)

	MT received	MT not received	*P*-value
Number	33	80	
Age, years	45.9 (±19.7)	45.9 (±21.8)	n.s.
Gender			n.s.
Male	20 (60.6%)	52 (65%)	
Female	13 (39.4%)	28 (35%)	
Interval between the onset of injury and the arrival at ED, min	32.3 (±12.1)	34.8 (±9.3)	n.s.
Injury mechanism			n.s.
Traffic accident	23 (69.7%)	60 (75.0%)	
Fall from a height	9 (27.3%)	15 (18.7%)	
Other mechanisms	1 (3.0%)	5 (6.3%)	
Vital signs on arrival			
SBP, mmHg	103.6 (±42.1)	138.6 (±31.0)	<0.001*
HR, /min	104.7 (±25.6)	85.0 (±22.0)	<0.001*
GCS	10.8 (±4.3)	11.7 (±4.3)	n.s.
Laboratory results [number of missing data]			
pH [0]	7.342 (±0.126)	7.388 (±0.063)	n.s.
Lactate, mg/dL [0]	42.2 (±27.7)	16.8 (±8.0)	<0.001*
Glucose, mg/dL [0]	188.7 (±59.2)	153.3 (±42.8)	<0.001*
Hemoglobin, g/dL [0]	11.7 (±2.6)	13.3 (±2.0)	<0.001*
WBC, /μL [0]	11,762 (±6,850)	10,759 (±3,902)	n.s.
Platelets, $\times 10^3/\mu L$ [0]	198.6 (±71.2)	230.7 (±62.2)	n.s.
Fibrin, mg/dL [15]	195.6 (±51.2) [6]	221.3 (±57.3) [9]	n.s.
FDP, mg/mL [11]	124.6 (±105.5) [2]	77.4 (±98.0) [9]	n.s.
PT-INR [4]	1.137 (±0.129) [2]	1.044 (±0.106) [2]	<0.001*
Ultrasonic/radiographic assessment			
FAST positive	10 (30.3%)	6 (7.5%)	0.0026*
Flat ratio of the IVC	3.86 (±1.36)	2.27 (±0.83)	<0.001*
Head AIS score ≥3	15 (45.5%)	36 (45.0%)	n.s.
Chest AIS score ≥3	12 (36.4%)	24 (30.0%)	n.s.
Abdomen AIS score ≥3	13 (39.4%)	5 (6.3%)	<0.001*
Pelvic AIS score ≥3	13 (39.4%)	12 (15%)	0.006*
ISS	29.9 (±13.6)	20.5 (±10.3)	<0.001*
Intervention for hemostasis			<0.001*
Operation	6 (18.2%)	0 (0%)	
Trans-arterial embolization	11 (33.3%)	3 (3.7%)	
Mortality at discharge	5 (15%)	7 (9%)	n.s.
Main cause of death			
Brain damage	2 (40.0%)	6 (85.7%)	
Hemorrhage	3 (60.0%)	1 (14.3%)	

AIS, Abbreviated Injury Scale; FDP, fibrinogen degradation products; FAST, focused assessment with sonography for trauma; GCS, Glasgow coma scale; HR, heart rate; ISS, Injury Severity Score; IVC, inferior vena cava; n.s., not significant; PT-INR, international normalized ratio of the prothrombin time; SBP, systolic blood pressure; WBC, white blood cells; *, P-value < 0.01.

score, which is determined by taking into account the mechanism of injury, vital signs (SBP and HR) and FAST positive findings. All three scoring systems included parameters that would be available in the primary survey in our study. They showed that an ABC score ≥2 was the best to identify patients who will require an MT, with a sensitivity of 0.75 and a specificity of 0.86. In the univariate analyses of our blunt trauma patients, the vital signs on arrival, such as the

Table 2. Predictors of the need for a massive transfusion obtained from primary and secondary surveys of patients with high-energy blunt injuries: results of logistic regression analysis

	Primary survey	*P*-value	Primary survey + secondary survey	*P*-value
Vital signs on arrival				
SBP ≤90 mmHg	3.29 (0.60–21.28)	n.s.	4.02 (0.58–39.97)	n.s.
HR ≥100/min	1.14 (0.28–4.09)	n.s.	0.72 (0.13–3.49)	n.s.
Laboratory data				
Lactate ≥28 mg/dL	17.56 (5.06–71.23)	<0.001*	105.11 (12.58–2,718.84)	<0.001*
Glucose ≥150 mg/dL	1.19 (0.36–3.85)	n.s.	0.86 (0.16–4.04)	n.s.
Hemoglobin ≤11 g/dL	3.61 (0.92–14.67)	n.s.	3.08 (0.54–20.97)	n.s.
PT-INR ≥1.1			0.27 (0.02–1.85)	n.s.
Radiographic assessment				
FAST positive	5.13 (1.00–26.15)	0.048*	2.90 (0.21–42.24)	n.s.
Flat ratio of the IVC ≥3			32.50 (4.44–714.44)	<0.001*
Abdomen AIS score ≥3			3.72 (0.34–53.54)	n.s.
Pelvic AIS score ≥3			5.25 (0.70–47.99)	n.s.
ISS ≥25			1.91 (0.39–10.53)	n.s.

AIS, Abbreviated Injury Scale; FAST, focused assessment with sonography for trauma; HR, heart rate; ISS, Injury Severity Score; IVC, inferior vena cava; n.s., not significant; PT-INR, international normalized ratio of the prothrombin time; SBP, systolic blood pressure; *, P-value < 0.05.

SBP and HR, indeed showed very high specificity, but low sensitivity for receiving an MT. Therefore, these two parameters were found to be non-significant predictors by the multivariate logistic regression analysis. One of our inclusion criteria was that the patient presented within 1 h post-trauma. Therefore, a certain number of patients in the current study were not in a hypotensive state even with ongoing bleeding, which may have led to the non-significance of the vital signs. In a Chinese population, Rainer *et al*.[15] sought to establish a new scoring system to predict the need for an MT, and defined this as ≥10 units PRBCs within 24 h in their case. Their scoring system was composed of seven independent variables: the SBP, Glasgow Coma Scale score, HR, presence of a displaced pelvic fracture, CT scan, or FAST positive for fluid, base deficit, and hemoglobin, and according to their categorization, the AUC and specificity for predicting the need for an MT were satisfactory, at 0.889 and 0.998, respectively, whereas the sensitivity was low, at 0.315. In contrast, using just two variables, one of which was derived from the secondary survey, we were able to show a higher AUC, sensitivity, and specificity in this study, and a simple linear predictive formula for the probability of the need to receive an MT was thus generated.

In previous studies, the blood lactate level has been well studied as an adjunct to increase the accuracy of detecting patients with an occult hypoperfusion state or early shock secondary to hemorrhage.[7,8,16–19] Recently, Vandromme *et al*.[8] reported that the blood lactate level was a better predictor, compared with the SBP, in identifying patients who required an MT, i.e., more than 6 units of PRBCs within 24 h post-injury in their study. They found that the risk of requiring an MT nearly doubled when blood lactate level increased to the range of 2.5–5.0 mmol/L (22.5–45.0 mg/dL), and the AUC for the prediction of receiving an MT was estimated at 0.76. Paladino *et al*.[7] showed that a lactate level of 2.5 mmol/L (22.5 mg/dL) or higher was the most efficient value for differentiating patients with major injuries who required a blood transfusion from those with minor injuries, but it had a low AUC of 0.64, with a sensitivity of 0.76 and a specificity of 0.49. In our series, confined to patients transferred within 1 h post-trauma, an elevated lactate level on arrival (≥28 mg/dL or 3.1 mmol/L) was also identified as a significant predictor of the need for an MT among a total of 11 variables, six from the primary survey and five from the secondary survey.

A flat IVC on the CT scan has also been reported as a good indicator of hypoperfusion in a trauma patient.[10,20–22] Mirvis *et al*.[21] noted that a flattened IVC was found in 10 of 13 patients who were clinically in a shock state after trauma. Matsumoto *et al*.[10] showed that patients with a flat IVC on the initial CT scan in cases of blunt torso trauma showed hemodynamic deterioration, thus necessitating early blood transfusion and therapeutic intervention. In our study, the flat ratio of IVC on CT was one of the most significant variables for predicting the need for an MT, and it greatly improved the predictive reliability. Traditionally, patients with unstable hemodynamics were recommended not to be transferred for CT scans. In such cases, FAST with simultaneous IVC

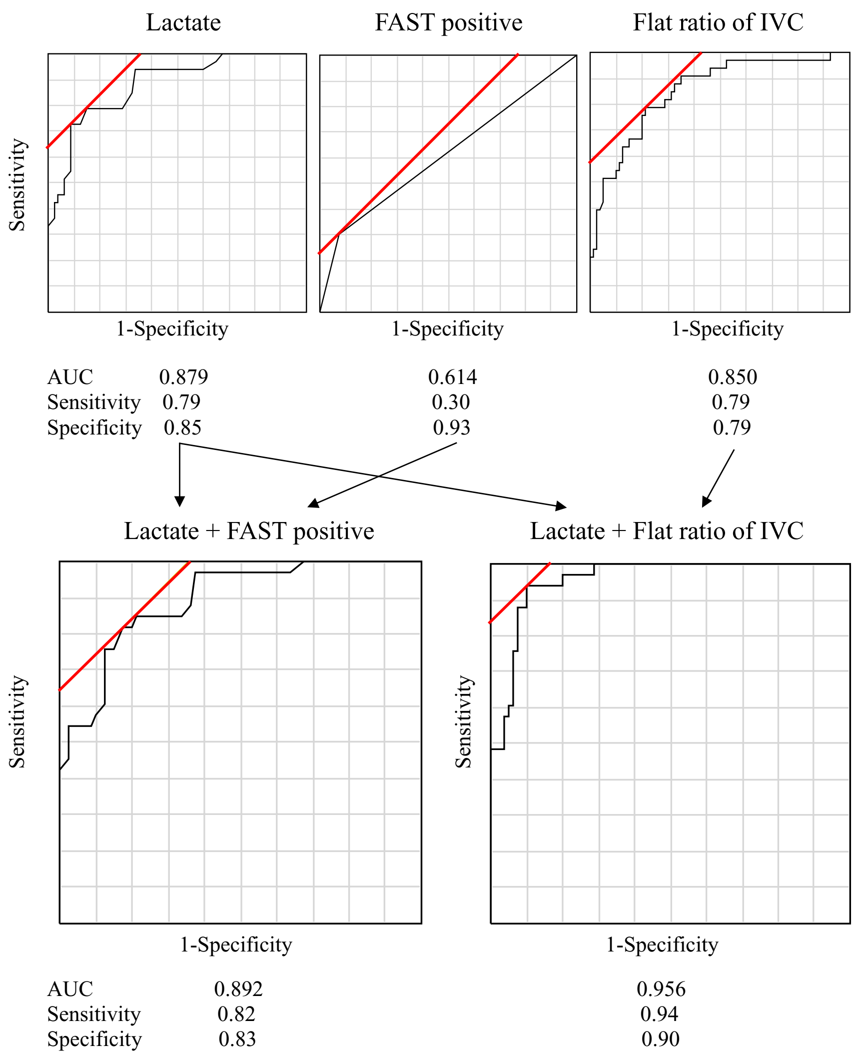

Fig. 1. Receiver operator curves were generated to evaluate the predictive strength of the most important factors for a massive transfusion: the lactate level, focused assessment with sonography for trauma (FAST) positive findings, and the flat ratio of the inferior vena cava (IVC). When a combination of the lactate level and the flat ratio of the IVC was used, the area under the curve (AUC) was increased up to 0.956, with a sensitivity of 0.940, a specificity of 0.90, a false positive ratio of 0.07, and a false negative ratio of 0.02. A linear predictive formula for the probability of needing a massive transfusion using the lactate level and the flat ratio of the IVC was generated, as follows: P = 2 × lactate (mg/dL) + 15 × the flat ratio of the IVC – 103.

assessment may be more feasible,[23,24] and warrants further study.

As the current study was a retrospective one, it has a limitation that should be kept in mind when generalizing its results. Among the total of 233 patients who fulfilled the inclusion criteria, important data, such as the arterial lactate level and the results of CT scans, were lacking for 120 patients, and they were all excluded from our analysis. We analyzed the clinical characteristics of these excluded 120 patients in order to compare with included patients (cf. Appendix Tables A1 and A2). In regard to mortality, there was no preventable trauma death (death with TRISS >0.5) out of 12 deaths in the excluded group, whereas there were 2 out of 12 in the included group. All four patients who died from hemorrhage had no abdominal CT scan because they were non-responders continued from the arrival. The other eight deaths were due to severe brain damage with no lesion in other body area. There was no difference in the main cause of death between the included and the excluded groups. Five patients who received an MT in the excluded group were two of deaths in the ED, two of pelvic fractures, and one of open fractures in the extremities. The excluded group showed significantly lower prevalence of chest, abdominal, and pelvic injuries compared to the included group, which resulted in lower ISS of the excluded group. That is, there was low possibility for life-threatening hemorrhage in the excluded group. This is one possible reason why the number of patients who received an MT was significantly less in the excluded group compared to the included group. Only five of the 120 excluded patients received an MT, therefore, the

Table 3. Results of validation study of patients with high-energy blunt injuries transferred within one hour post-trauma

	MT received	MT not received	*P*-value
Number	19	33	
Age, years	49.6 (±19.2)	44.5 (±20.1)	n.s.
Gender			n.s.
Male	12 (63.2%)	27 (81.8%)	
Female	7 (36.8%)	6 (18.2%)	
ISS	29.8 (±14.4)	20.0 (±9.1)	0.004
Lactate, mg/dL	63.7 (±39.9)	21.5 (±13.2)	<0.001*
Flat ratio of the IVC	3.67 (±1.76)	2.18 (±0.71)	<0.001*
P-value by predictive formula			<0.001*
Positive	16	2	
Negative	3	31	

Accuracy rate of the predictive formula 0.904, sensitivity 0.84, specificity 0.94. ISS, Injury Severity Score; IVC, inferior vena cava; MT, massive transfusion; n.s., not significant; *, P-value < 0.05.

influence of this exclusion on our current results, especially in regard to false negative, can be considered marginal.In addition, the results of a retrospective validation study in another patient series indicated a high accuracy rate for predicting an MT. The patients examined for venous lactate level were not included because venous lactate tends to be overestimated.[25] Even though the linear predictive formula in this study was obtained from the retrospectively selected patients, we believe this study can be an important attempt to recognize patients who require MT at the early stage of blunt trauma according to the concept of "the golden hour" after high-energy trauma in Advanced Trauma Life Support. Importantly, further studies are needed to validate the formula prospectively and examine patients in other institutes.

CONCLUSION

THE ELEVATED LEVEL of arterial lactate and the flat ratio of IVC were the best predictors for identifying the patients who would need to receive a MT in the early stage after high-energy blunt trauma. Using a combination of the two variables, a simple predictive formula for the probability of receiving an MT was generated: $P = 2 \times \text{lactate (mg/dL)} + 15 \times \text{the flat ratio of the IVC} - 103$. This may be helpful in determining the prognosis of patients in the ED.

CONFLICT OF INTEREST

NONE.

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APPENDIX

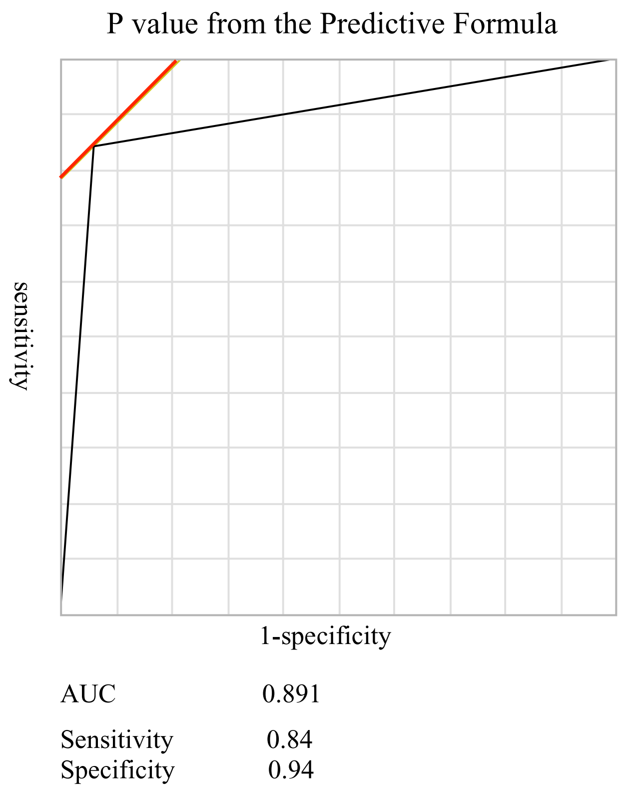

Fig. A1. Receiver operator curve was generated to evaluate the predictive strength of the predictive formula for a massive transfusion. The area under the curve was 0.891, with a sensitivity of 0.84, a specificity of 0.94, a false positive ratio of 0.11, and a false negative ratio of 0.09.

Table A1. Comparison of clinical characteristics between patients with high-energy blunt injuries transferred within one hour post-trauma who were included and excluded in this study

	Included patients	Excluded patients	*P*-value
Number	113	120	
Age, years	45.9 (±21.1)	44.5 (±21.8)	n.s.
Gender			n.s.
Male	72 (63.4%)	83 (69.1%)	
Female	41 (36.6%)	37 (30.9%)	
Interval between the onset of injury and the arrival at the ED, min	34.1 (±10.2)	33.2 (±10.7)	n.s.
Number of patients who received an MT	33 (29.2%)	5 (4.1%)	<0.001*
Mortality	12 (10.6%)	12 (10.0%)	n.s.
Preventable trauma death (death with TRISS >0.5)	2/12	0/12	
Main cause of death			
Brain damage	8 (66.7%)	8 (66.7%)	
Hemorrhage	4 (33.3%)	4 (33.3%)	
Vital signs on arrival			
SBP, mmHg	127.9 (±37.8)	133.7 (±36.4)	n.s.
HR, /min	90.7 (±24.7)	84.7 (±22.5)	n.s.
GCS	11.5 (±4.3)	12.5 (±3.9)	n.s.
Ultrasonic/radiographic assessment			
ISS	23.2 (±12.1)	17.0 (±8.6)	<0.001*
>34	24 (21%)	9 (8%)	
17< ISS <33	54 (48%)	37 (31%)	
<16	35 (31%)	73 (61%)	
FAST positive	16 (14.2%)	4 (3.3%)	0.0041*
Head AIS score ≥3	15 (45.1%)	57 (47.5%)	n.s.
Chest AIS score ≥3	36 (31.8%)	22 (18.3%)	0.0226*
Abdomen AIS score ≥3	18 (15.9%)	4 (3.3%)	0.0013*
Pelvic AIS score ≥3	25 (22.1%)	11 (9.2%)	0.0067*
Spine AIS score ≥3	19 (16.8%)	24 (26.1%)	n.s.
Extremities AIS score ≥3	45 (39.8%)	31 (33.7%)	n.s.

AIS, Abbreviated Injury Scale; ED, emergency department; FAST, focused assessment with sonography for trauma; GCS, Glasgow coma scale; HR, heart rate; ISS, Injury Severity Score; MT, massive transfusion; n.s., not significant; SBP, systolic blood pressure; TRISS, Trauma and Injury Severity Score; *, P-value < 0.05.

Table A2. Detailed profile of clinical characteristics in patients with high-energy blunt injuries transferred within one hour post-trauma who were excluded from this study

Excluded patients (n = 120)	No arterial blood gas data	No abdominal CT data	No data for either
Number	98 of 120	44 of 120	32 of 120
Mortality	4 (5.5%)	10 (22.7%)	4 (12.5)
Brain damage	2	6	
Hemorrhage	2	4	
ISS	16.3 (±8.1)	17.0 (±8.7)	
>34	5 (5%)	4 (9%)	
17< ISS <33	29 (30%)	11 (25%)	
<16	64 (65%)	29 (66%)	
Number of patients who received a MT	3 (3.1%)	2 (4.5%)	
Head AIS score ≥3	48 (48.9%)	23 (52.3%)	
Chest AIS score ≥3	13 (13.2%)	6 (13.6%)	
Abdomen AIS score ≥3	3 (3.1%)	0 (0%)	
Pelvic AIS score ≥3	10 (10.2%)	1 (2.3%)	
SBP, mmHg	134.4 (±35.9)	122.6 (±36.9)	
HR, /min	86.8 (±22.3)	78.2 (±24.4)	
GCS	12.8 (±3.6)	11.9 (±4.5)	

AIS, Abbreviated Injury Scale; CT, computed tomography; GCS, Glasgow coma scale; HR, heart rate; ISS, Injury Severity Score; MT, massive transfusion; SBP, systolic blood pressure.